Forecourt-Specific Assumptions and Groundrules for H2A Analyses

October 2005

The following specific cost and design assumptions are applicable to all H2A forecourt supply options unless specified otherwise below. They are meant to augment the general guidelines listed in "Common Assumptions and Groundrules". For all cases, a "Small Station" is designed to produce and dispense a maximum of 100kg H_2/day, and a "Large Station" is designed to produce and dispense a maximum of 1,500 kg H2/day. Both small and large stations are assumed to be integrated into existing medium-sized (~ 8 dispensers total) fueling stations; i.e., both gasoline and hydrogen are available at the fueling station.

Performance Assumptions Tab

Process Efficiency: Summary tables for sub and overall efficiency assumed for each case appear below.

1,500 kg/day NG SR System Performance Parameters

	Current	Advanced	Longer Term
Production System Feedstock Consumption (kWh Feedstock (LHV)/kg of H2)	48.3	46.3	45.7
Production Unit Hydrogen Efficiency (%)	69.0%	72.0%	73.0%
Production Electricity Consumption (kWhe/kg of H2)	1.5	1.3	1.3
Production H2 Leak (%)	0%	0%	0%
Production Step Efficiency (%)	67.6%	70.5%	71.5%
Compression, Storage and Dispensing Feedstock Consumption (kWh (LHV)/kg of H2)	0.0	0.0	0.0
Compression, Storage and Dispensing Electricity Consumption (kWhe/kg of H2)	2.2	2.2	2.2
Compression, Storage and Dispensing H2 Leak (%)	0%	0%	0%
Compression, Storage and Dispensing Step Efficiency (%)	93.7%	93.7%	93.7%
Total H2 Leak (%)	0%	0%	0%
Total System Efficiency (%)	63.8%	66.4%	67.2%
Process water consumption (L/kg of H2)	22.68	22.68	22.68

100 kg/day NG SR System Performance Parameters

	Current	Advanced	Longer Term
Production System Feedstock Consumption (kWh Feedstock (LHV)/kg of H2)	49.02	46.94	46.29
Production Unit Hydrogen Efficiency (%)	68%	71%	72%
Production Electricity Consumption (kWhe/kg of H2)	2.4	1.75	1.75
Production H2 Leak (%)	0%	0%	0%
Production Step Efficiency (%)			
Compression, Storage and Dispensing Feedstock Consumption (kWh (LHV)/kg of H2)	0.0	0.0	0.0
Compression, Storage and Dispensing Electricity Consumption (kWhe/kg of H2)	2.2	2.2	2.2
Compression, Storage and Dispensing H2 Leak (%)	0%	0%	0%
Compression, Storage and Dispensing Step Efficiency (%)	93.7%	93.7%	93.7%
Total H2 Leak (%)	0%	0%	0%
Total System Efficiency (%)	64%		
Process water consumption (L/kg of H2)	22.68	22.68	22.68

100 kg/day and 1,500 kg/day Electrolyser System Performance Parameters

	Current	Advanced	Longer Term
Production System Feedstock Consumption (kWh Feedstock (LHV)/kg of H2)	-	-	-
Production Unit Hydrogen Efficiency (%)	64%	71%	76%
Production Electricity Consumption (kWhe/kg of H2)	52.08	46.94	43.86
Production H2 Leak (%)	0%	0%	0%
Production Step Efficiency (%)	64%	71.0%	76.0%
Compression, Storage and Dispensing Feedstock Consumption (kWh (LHV)/kg of H2)	0.0	0.0	0.0
Compression, Storage and Dispensing Electricity Consumption (kWhe/kg of H2)	2.23	2.23	2.23
Compression, Storage and Dispensing H2 Leak (%)	0%	0%	0%
Compression, Storage and Dispensing Step Efficiency (%)	93.7%	93.7%	93.7%
Total H2 Leak (%)	0%	0%	0%
Total System Efficiency (%)	61.3%	67.8%	72.3%
Process water consumption (L/kg of H2)	11.12	11.12	11.12

Forecourt Parameters Tab:

- Design Capacity – 2 kg/min – Design rate of hydrogen transfer to the vehicle based on DOE targets[1]. Note that testing confirms this rate is feasible with 6,250psi supply pressure and no H_2 cooling.

- Storage/Dispensing Technology – Cascade storage and dispensing for all on-site production stations. Liquid hydrogen (LH_2) storage with a combination of LH_2 pump/evaporation and cascade dispensing for the delivered LH_2 stations. Tube trailer storage with a combination of compressor and cascade dispensing for the tube trailer station. No storage and cascade dispensing for the pipeline station.

- H_2 Dispensing Temperature – 20°C – assumes typical ambient temperature. Note that testing confirms 2 kg/min is feasible with 6,250psi supply pressure and no H_2 cooling.

- Maximum H_2 Dispensing Pressure – 431 bar (6,250psi) - required for complete fill-up to 345 bar (5,000 psi) on-board the vehicle. Note that testing confirms 2 kg/min is feasible with 6,250psi supply pressure and no H_2 cooling.

- Average Fill-up Capacity – 6 kg/fill – Based on FreedomCAR Tech Team targets which assume an average hydrogen vehicle fleet tank size of 8 kg that needs to be refilled at 75% of maximum capacity. Note that current hydrogen vehicles have 4-5kg H_2 tanks.

- Number of H_2 Dispensers per Station - 1 dual H_2 dispenser (2 hoses) for small station, 3 dual H_2 dispensers (6 hoses) for large station.

- H_2 Storage Design Capacity – This is the total amount of hydrogen stored at the station. Calculated as follows: maximum daily production X % Storage / Usable Fraction.

- H_2 % Storage: This is the % of daily maximum H_2 production that needs to be stored to allow adequate H2 transfer to vehicles based on refueling load profile and the H_2 production rate (if any). Based on the Forecourt Team assumed daily demand profile, number of vessels, and maximum, minimum, and intermediate storage pressures, on-site production cases use 35%.

- H_2 Usable Fraction – This is the fraction of hydrogen stored in on-site compressed gas storage vessels than can be dispensed to vehicles at adequate pressure. Based on Forecourt Team analysis, 44% is used for all cases.

- LH_2 Pump Maximum Pressure – 6,250 psi

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[1] Hydrogen, Fuel Cells, and Infrastructure Technologies Program, "Mulit-year Resarch, Development, and Demonstration Plan", US DOE, DRAFT (June 3, 2003), http://www.eere.energy.gov/hydrogenandfuelcells/mypp/

- LH_2 Storage Boil-off – 0.4%, 0.2%, and 0% per day (of maximum tank volume) for current, mid-term, and long-term cases, respectively. Assumes improvement in boil-off management over time.

- Total H_2 Fueling Operations Footprints – See table below (based on site plans). Note that addition of hydrogen storage and dispensing capacity can significantly increases station footprint due to standoff distances. Not all existing refueling stations may be able to accommodate footprint growth.

	Small Station (100kg/day)	Large Station (1,500 kg/day)
Reformer Production	2,206 ft^2	7,199 ft^2
Electrolyser Production	2,206 ft^2	7,199 ft^2
cH_2 Station (Tube Trailer and Pipeline)	-	-
LH_2 Dispensing	-	-

- Site Plan: See Figure 1.

Daily H2 Demand Profile Tab:

- Load Profile – See

Figure 2 below. Note that load profile is consistent with industry design "rule of thumb" that 40% of fuel is dispensed in 2-3 hour period.

Financial Inputs Tab:

- Plant Life: Plant life is always assumed to be 20 years based on the assumption that the overall plant will be dated and/or obsolete after 20 years even if portions are periodically replace. However, major portions of the equipment may have a lesser useful life. This is reflected on the Replacement Capital Tab.

- Capacity Factor – 70% - The overall average capacity factor is the net result of four influences:

    - 20% weekday to weekend surge factor
    - 10% seasonal surge factor
    - 5% statistical surge factor
    - 3% for scheduled downtime.

  A mature hydrogen market is assumed (i.e., adequate hydrogen demand to meet the supply). The H2A is not evaluating a transition scenario.

- Length of Construction: All forecourt stations are assumed to be factory built modules trucked into the forecourt site and rapidly assembled. Consequently, the length of construction is set to zero to approximate this scenario.

- Start-Up Time: 1 year. It is assumed that it only takes one year for the forecourt station to establish itself and achieve full production (ie. Plant Design Capacity times Operating Capacity Factor).

- % Revenue During Start-Up: 50%

- % of Variable and Fixed Operating Costs During Start-Up: Both 50%

- Salvage Value: Set at 0% for all cases however if a particular major component has residual value at the end of the 20 year plant life (by virtue of its replacement schedule), the residual value is credited as a negative cost on the Replacement Capital Tab.

- Salvage Value – Assumes linear decrease in plant value (initial capital cost) over the lifetime of the plant. Because all forecourt analyses are conducted with a 20-year analysis period, salvage value need only be computed for cases where there is a 15-year system life. In that case, the salvage value is credited as a negative cost on the Replacement Capital Tab.

Cost Inputs Tab:

- Capital Investment: Summary tables for uninstalled capital investments assumed for each case appear below.

Production Subsystem

	Current	Basis	Advanced	Basis	Longer Term	Basis
1,500 kg/day NG SR	$1,172,478	Forecourt Team Consensus	$897,783	Forecourt Team Consensus	$824,085	Forecourt Team Consensus
100 kg/day NG SR	$175,000	Forecourt Team Consensus	$134,000	Forecourt Team Consensus	$123,000	Forecourt Team Consensus
1,500kg/day Electrolyser	$2,164,497	$665/kWinput at 64% LHV efficiency for large station.	$1,173,592	$400/kWinput at 71% LHV efficiency for large station	$822,286	$300/kWinput at 76% LHV efficiency for large station
100 kg/day Electrolyser	$307,912	$1419/kWinput at 64% LHV efficiency for small station.	$165,281	$845/kWinput at 71% LHV efficiency for small station.	$116,947	$640/kWinput at 76% LHV efficiency for small station.

H2 Compression Subsystem

	Current	Basis	Advanced	Basis	Longer Term	Basis
1,500kg/day H2 Compressor Subsystem	$286,250	$4580/(kg/hr), 4-stage, piston compressor, 300psi inlet, 6250psi outlet.	$286,250	$4580/(kg/hr), 4-stage, piston compressor, 300psi inlet, 6250psi outlet.	$286,250	$4580/(kg/hr), 4-stage, piston compressor, 300psi inlet, 6250psi outlet.
100 kg/day H2 Compressor Subsystem	$26,250	$6300/(kg/hr), 4-stage, piston compressor, 300psi inlet, 6250psi outlet.	$26,250	$6300/(kg/hr), 4-stage, piston compressor, 300psi inlet, 6250psi outlet.	$26,250	$6300/(kg/hr), 4-stage, piston compressor, 300psi inlet, 6250psi outlet.

H_2 Storage Subsystem

	Current	Basis	Advanced	Basis	Longer Term	Basis
1,500kg/day Storage Subsystem	$976,023	$818/kg H2 stored based on ASME metal cylinders holding 14kg each at 6250psi. Includes peripherals and mounting structures. (Based on vendor quote extrapolated to high volume)	$385,398	$323/kg H2 stored based on composite cylinders. Includes peripherals and mounting structures. (Based on modified price quotes from Quantum.)	$353,182	$296/kg H2 stored based on composite cylinders. Includes peripherals and mounting structures. (Based on modified price quotes from Quantum.)
100kg/day Storage Subsystem	$65,068	$818/kg H2 stored based on ASME metal cylinders holding 14kg each at 6250psi. Includes peripherals and mounting structures. (Based on vendor quote extrapolated to high volume)	$42,716	$537/kg H2 stored based on composite cylinders. Includes peripherals and mounting structures. (Based on modified price quotes from Quantum.)	$37,386	$470/kg H2 stored based on composite cylinders. Includes peripherals and mounting structures. (Based on modified price quotes from Quantum.)

Dispenser Subsystem

	Current	Basis	Advanced	Basis	Longer Term	Basis
1,500kg/day Dispensor System	$67,200	Reflects dual hose 6250kpsi rated H2 dispenser with card reader. Based on 3 dispensers. (Based on vendor quote extrapolated to high volume)	$67,200	Reflects dual hose 6250kpsi rated H2 dispenser with card reader. Based on 3 dispensers. (Based on vendor quote extrapolated to high volume)	$67,200	Reflects dual hose 6250kpsi rated H2 dispenser with card reader. Based on 3 dispensers. (Based on vendor quote extrapolated to high volume)
100 kg/day Dispensor System	$22,400	Reflects dual hose 6250kpsi rated H2 dispenser with card reader. Based on 1 dispenser. (Based on vendor quote extrapolated to high volume)	$22,400	Reflects dual hose 6250kpsi rated H2 dispenser with card reader. Based on 1 dispenser. (Based on vendor quote extrapolated to high volume)	$22,400	Reflects dual hose 6250kpsi rated H2 dispenser with card reader. Based on 1 dispenser. (Based on vendor quote extrapolated to high volume)

Overall Control & Safety Equipment Subsystem

	Current	Basis	Advanced	Basis	Longer Term	Basis
Overall Control & Safety Equipment	$18,600	Fire detector, alarms, controls, etc. based on detailed site plan	$18,600	Fire detector, alarms, controls, etc. based on detailed site plan	$18,600	Fire detector, alarms, controls, etc. based on detailed site plan

Forecourt SMR Capital Cost: While the above tables summarize the basis and actual capital cost values used in the spreadsheets, the input and methodology used by the forecourt team to form a decision appears below.

For Forecourt SMR Production Unit, Uninstalled, 500 units/year Production Rate

Cost Estimates Based on:

1) 2005 100kg/day Unit cost based on re-examination of detailed studies available in the literature and influenced by input from the KIC (Key Industrial Contacts).
2) 2015 and 2030 cost estimates were based on H2A Forecourt teams best engineering judgement and input form the KIC. (25% cost reduction for 2015 and 30% total cost reduction for 2030)
3) Input from the KIC and Scaling Factors (based on 100kg/day unit) were used to determine cost for the larger 1500kg/day unit.
4) Learning curve estimates were used to verify reasonableness of unit costs selected.

SMR Reformer, 100kg/day

Learning Curve Exponential = 0.93

Year	Cumulative Unit Number	Price	Used in Analysis
2004	5	$280,000	
2005	505	$172,707	$175,000
2015	5505	$134,490	$134,000
2030	13005	$122,914	$123,000

SMR Reformer, 1500kg/day

Cost Scaled from 100kg/day unit
Based on capacity Ratio using scaling factor ^0.6
and assuming two side-by-side units of 750kg/day
to reach total 1500kg/day capacity

Year	Price	Used in Analysis
2004	$1,875,965	
2005	$1,172,478	$1,172,478
2015	$897,783	$897,783
2030	$824,085	$824,085

	Subsystem Cost (Ref. 1)	Subsystem Cost With Additional 15% added for each subsystem and an additional Miscellaneous Category (12%)	Scaling Exponent (New Capcity/Old Capacity)^ exponent	Scaling to a 750kg/day unit	10% discount due to increased manufacturing rate (two 750kg/day units instead of one 1500kg/day unit)
NG Compressor Subsystem	$3,257	$3,746	0.75	$16,976	$15,278.03
Hydro-Desulfurization Subsystem	$4,883	$5,615	0.6	$18,811	$16,929.92
Boiler Subsystem	$14,974	$17,220	0.6	$57,687	$51,918.68
Reformer Subsystem	$34,407	$39,568	0.6	$132,550	$119,295.11
Shift Subsystem	$21,678	$24,929	0.6	$83,512	$75,160.61
Condensor Subsystem	$3,286	$3,779	0.6	$12,658	$11,392.13
Water Purification Subsystem	$3,531	$4,061	2x	$8,121	$7,309.17
PSA Subsystem	$19,883	$22,865	0.95	$155,052	$139,546.69
Prod. Unit Structural Supports & Building	$6,340	$7,291	0.7	$29,878	$26,890.56
Instruments/Controls Subsystem	$15,491	$17,815	2x	$35,630	$32,066.99
Prod. Unit Assembly	$8,171	$9,396	0.7	$38,504	$34,653.56
Miscellaneous	$0	$18,754	0.6	$62,826	$56,543.11
Total	$135,901	$175,040		$652,205	$586,985
				Total Cost for 1500kg/day capacity (two 750kg/day units) =	$1,173,969.15

Ref 1: "Cost & Performance Comparison of Stationary Hydrogen Fueling Appliance", Duane Myers, Greg Ariff, Brian James, John Lettow, Sandy Thomas, Reed Kuhn, Directed Technologies Inc., April 2002 completed for The Hydrogen Program Office, US DOE as the Task 2 Report under Grant No. DE-FG01-99EE35099.

Ref 2:Arthur D. Little, "Guidance for Transportation Technologies: Fuel Choice for Fuel Cell Vehicles, Phase II Final Report", available at http://www-db.research.anl.gov/db1/cartech/document/DDD/192.pdf, February 2002 , slide 71 of Main Report.

Estimates from the KIC were solicited as further input to the forecourt team SMR capital cost decision.

	2005 Estimated Price	2005 Basis	2015 Estimated Price	2015 Basis	2025 Estimated Price	2025 Basis
Production Unit (NG SMR Reformer)	**$175k**	**H2A Estimate at 500/yr**	**$135k**	**H2A Estimate at 500/yr**	**$123k**	**H2A Estimate at 500/yr**
100kg/day	$200-$250k	Company A at 500/yr.				
Uninstalled	"$175k not unbelievable"					
	$280k	Company B at Q 1-5				
	$480k	Company D at 100/yr				
	$900k	National Acadamy Estimate, "Current Tech", "Low" Production", 480kg/day			$480k	National Acadamy Estimate, "Future Optimistic", "Low" Production", 480kg/day
Production Unit (NG SMR Reformer)	**$1.17M**	**H2A Estimate at 500/yr**	**$898k**	**H2A Estimate at 500/yr**	**$824k**	**H2A Estimate at 500/yr**
1500kg/day	$2M	Company A, first unit	$2M	Company A, first unit	$200k	Company C, high volume
Uninstalled	$2.07M	Company B, Q 1-5 (based on three 575kg/day units)	$900k	Company A, 500/yr lower bound		
	$1.38M	Company B, Q 10-25 (based on three 575kg/day units)	$1.2M	Company A, 500/yr baseline		
	$2.6M	Company D, Q unspecified (based on two 860kg/day units)	$1.5M	Company A, 500/yr upper bound		
	$2.7M	National Acadamy Estimate, "Current Tech", "Low" Production", based on three units of 480kg/day			$1.44M	National Acadamy Estimate, "Current Tech", "Low" Production", based on three units of 480kg/day

- Installation Factors- % multiplier on component capital cost. Includes site work and based on installation at green-field.

    - Production System Components: 10%
    - Compressor System Components: 20%
    - Storage System Components 10%
    - Dispensing System Components 20%

Details of the installation cost basis appear below:

Production System

Subsystem Capital Cost	$213,206	
Subsystem Installation		
Sales Tax	$10,660	5% of capital cost
Shipping	$1,500	Average of multiple price quotes, 750 miles one-way, 6000lbs, dedicated truck
Shipping Insurance	$2,132	1% of capital cost
Crane Rental	$880	8 hours at $110/hr, 20-ton one-man crane
Line Connections	$600	16 hours at $75/hour
Foreman/Worker	$3,200	5 days, $50/hr foreman, $30/hour worker
Commissioning/Certification	$0	0 days at $200/hour (because UL Listed)
Total	$18,972	
Installation Cost as % of Capital Cost	9%	
Forecourt Team Recommended Installation %	**10%**	

Compressor System

Subsystem Capital Cost	$27,383	
Subsystem Installation		
Sales Tax	$0	0% of capital cost (sales tax originally included, then set to zero per Forecourt team consensus)
Shipping	$800	Estimate
Shipping Insurance	$274	1% of capital cost
Crane Rental	$880	8 hours at $90/hr, 20-ton one-man crane
Line Connections	$600	8 hours at $75/hour
Foreman/Worker	$1,280	2 days, $50/hr foreman, $30/hour worker
Commissioning/Certification	$0	0 days at $200/hour (because UL Listed)
Total	$3,834	
Installation Cost as % of Capital Cost	14%	
Forecourt Team Recommended Installation %	**20%**	

Storage System

Subsystem Capital Cost	$86,000	
Subsystem Installation		
Sales Tax	$0	0% of capital cost (sales tax originally included, then set to zero per Forecourt team consensus)
Shipping	$1,500	Average of multiple price quotes, 750 miles one-way, 6000lbs, dedicated truck
Shipping Insurance	$860	1% of capital cost
Crane Rental	$880	8 hours at $90/hr, 20-ton one-man crane
Line Connections	$600	8 hours at $75/hour
Foreman/Worker	$1,280	2 days, $50/hr foreman, $30/hour worker
Commissioning/Certification	$0	0 days at $200/hour (because UL Listed)
Total	$5,120	
Installation Cost as % of Capital Cost	6%	
Forecourt Team Recommended Installation %	**10%**	

Dispenser

Subsystem Capital Cost	$22,800	
Subsystem Installation		
Sales Tax	$0	0% of capital cost (sales tax originally included, then set to zero per Forecourt team consensus)
Shipping	$232	Average of 7 price quotes, 750 miles one-way, 350lbs
Shipping Insurance	$228	1% of capital cost
Forklift Rental	$880	4 hours at $50hr
Line Connections	$600	4 hours at $75/hour
Foreman/Worker	$640	1 day, $50/hr foreman, $30/hour worker
Commissioning/Certification	$0	0 days at $200/hour (because UL Listed)
Total	$2,580	
Installation Cost as % of Capital Cost	11%	
Forecourt Team Recommended Installation %	**20%**	

- Site Preparation (including 20% markup for General Contractor fees) – includes civil (e.g., trenching, concrete), electrical (e.g., wiring, switchgear), and mechanical and piping (e.g., hydrogen conduits, fencing, signage)

o	Small Station (100kg/day)	Large Station (1,500 kg/day)
Reformer Station	$34,128	$74,344
Electrolyser Station	$34,128	$74,344
cH_2 Station (Tube Trailer and Pipeline)	$32,646	$65,534
LH_2 Station	$35,505	$76,186

- Station Engineering and Design - $30,000 – Includes construction management. Note that some industry representatives indicated that this number could be as high as $150,000 independent of station size.

- Project Contingency – 10% of total direct depreciable capital investment – consistent with Central Plant assumption. Assumes capital costs are based on quotes given in a mature hydrogen market (i.e., adequate hydrogen demand to meet the supply). The H2A is not evaluating a transition scenario. Note that some industry representatives indicated that this % could be much higher.

- Up-front Permitting Cost - $28,000 - Includes multiple visits to multiple agencies and a public review/ comment process. Based on estimate of $56,000 for the whole station with 50% judged attributable to H_2 operations (56,000* 50% = $28,000). Note that some industry representatives indicated that this number could be much higher.

- Land Required/Cost of Land: See site plans. Land is not purchased but rather is assumed to be rented. See Annual Rent below.

- Production Unit Labor Hours Required: Zero. On-site production units are assumed to be unmanned.

- Annual H_2 Storage/Dispensing Labor Hours Required – large station = 1232 hours/yr, small station = 410 hours/yr - assumes station is “self-serve” not “full service”. Labor is for employee to collect money at kiosk, sell other goods, etc. Based on 18 hours/day, 365 days/year, 50% of labor cost attributable to fueling operations and 50% to convenience store operations. Labor hours are further split between H_2 fueling operations and gasoline fueling operations based on the number of dispensers. Thus for a large station, annual H_2 dispensing labor would be 18 hours/day * 365 days/year * 50% fueling fraction * (3 H_2 dispensers/8 total dispensers).

- H_2 Storage/Dispensing Labor Rate- $15 per hour

- Overhead and General & Administrative (G&A) Rate – 20% of total station labor cost (H_2 refueling operations only, does not include convenience store operations) – consistent with Central Plant assumption.

- Annual Rent - \$0.50/ft^2 per month - Area based on portion of station dedicated to hydrogen refueling operations (hydrogen production or delivery, storage, and dispensing), does not include convenience store or store parking footprint.

- Annual Licensing, Permits, and Fees - \$1000/year – Includes water, electrical, fire equipment, and storage tank inspections.

- Annual Production Maintenance and Repairs: These annual costs are in addition to the specific equipment replacement costs shown on the "Replacement Cost Tab".

	Small Station	Large Station
Production	7% of Production Initial Capital Investment (Depreciable)	5% of Production Initial Capital Investment (Depreciable)
Compression	5% of Compression Initial Capital Investment (Depreciable)	3% of Compression Initial Capital Investment (Depreciable)
Storage	1% of Storage Initial Capital Investment (Depreciable)	1% of Storage Initial Capital Investment (Depreciable)
Dispensing	\$800/dispensor for dispensor O&M and M&R	\$800/dispensor for dispensor O&M and M&R

- Annual Forecourt Maintenance and Repairs: Included in table above.

- Feedstock Price Assumptions – Commercial natural gas and electricity prices are assumed for the all small stations and for large station delivered hydrogen. Industrial prices are assumed for the large station on-site production from natural gas or electricity. Average annual throughput would be 45,990 GJ/yr (435,900 Therms/yr) for natural gas from the large stations. In addition, several utilities offer discounts for natural gas or electricity if they are used for transportation applications (e.g., CNG or plug-in electric vehicles). Feedstock prices are held constant over the analysis period at the feedstock cost of the startup year.

- Other variable operating costs: This covers waste disposal costs, non-feedstock fuels, environmental surcharges, etc. and is estimated at \$800/month with 50% being attributed to refueling operations (the other 50% goes to convenience store operations) and is further pro-rata for the fraction of hydrogen dispensers out of total dispensers (3 out of 8 for large stations, 1 out of 8 for small stations). Thus for a large station, annual "Other Variable Costs" are \$800/month * 12 months/year * 50% fueling fraction * (3 H_2 dispensers/8 total dispensers) = $1,800/year.

- Operator Profit – $0.00 – IRR calculation accounts for profit (i.e., return on investment). No additional markup for fueling operations beyond pricing set to achieve target IRR.

Replacement Cost Tab:

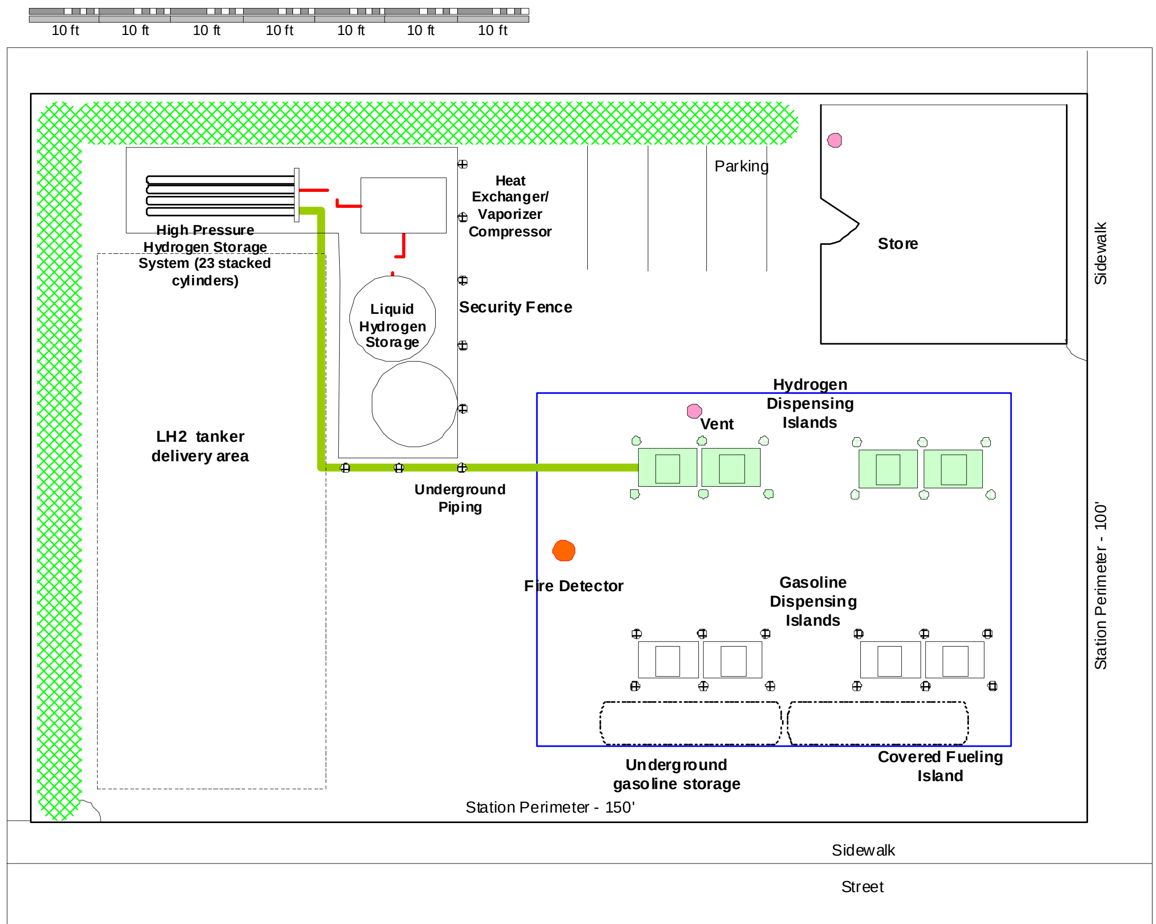
- Total Yearly Replacement Cost – Equipment replacement and refurbishment cost is assessed according to the schedule below.

Reformer System Catalyst/Reactor Replacement or Refurburishment	15% of initial capital cost every 5 years
Electrolyser System Major Overhaul	30% of initial capital cost every 7 years

Additionally, major subsystems are assumed to various useful lifetimes as shown below. When a plant exceeds in lifetime, it is replace at 100% of its original installed capital cost. Interval at which entire (sub)system is replaced. All equipment lasts 20 years unless noted below.

	2005	**2015**	**2030**
Reformer Unit (NG/MeOH/Eth.)	10 years	15 years	20 years
Dispenser	10 years	10 years	10 years
Other Subsystems (compressors, storage)	20 years	20 years	20 years

Figure 1a,b,c : Forecourt Site Plans for Several Production and Dispensing Options



Property of:
TIAX LLC
1061 De Anza Blvd.
Cupertino, CA 95014

10 ft

Site Plan - Fueling Station

Combined Liquid Hydrogen and Gasoline High Volume Station

SIZE	DWG BY	DWG NO	REV
A	Erin Kassoy	D0228 - S0024	3

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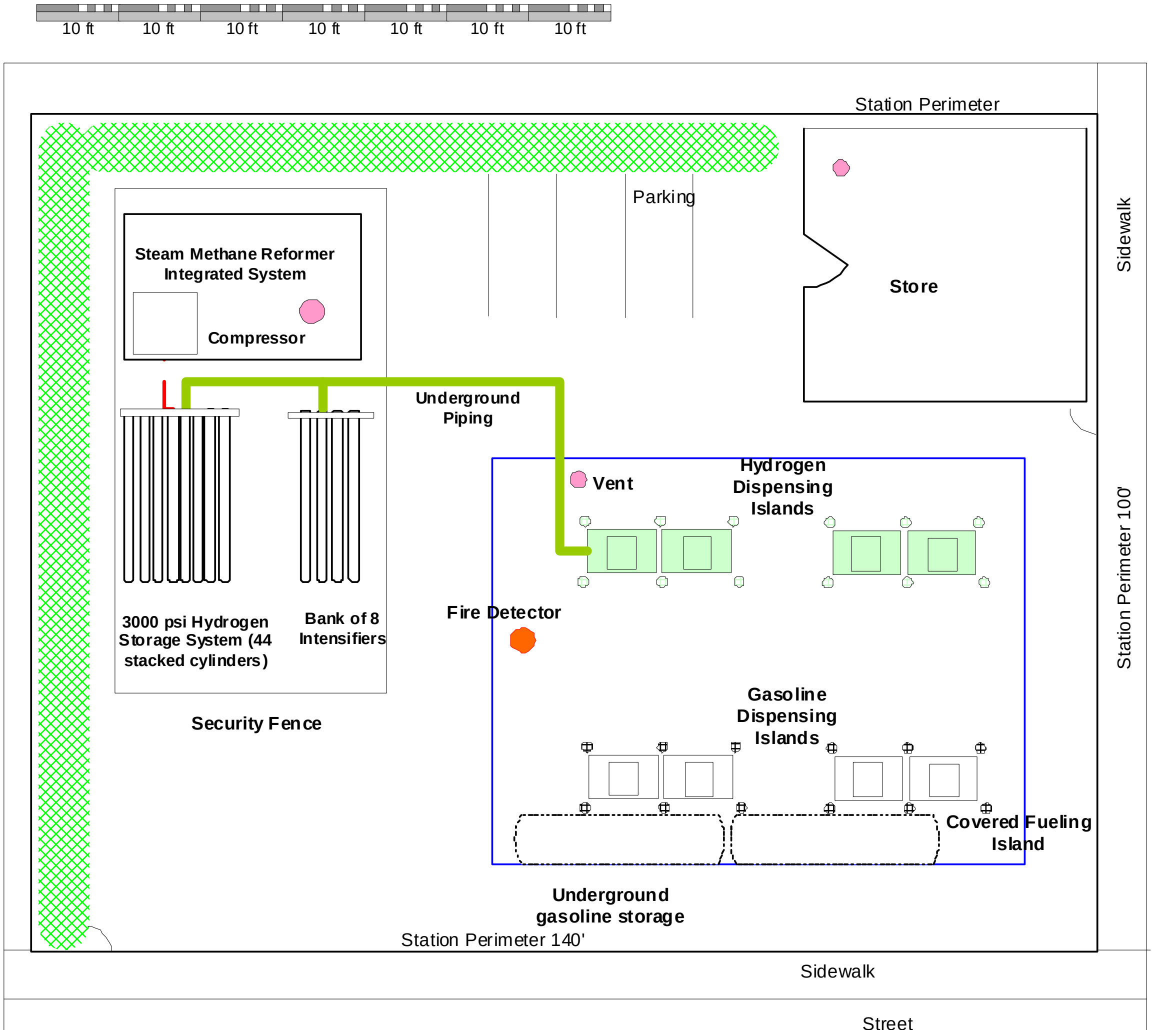
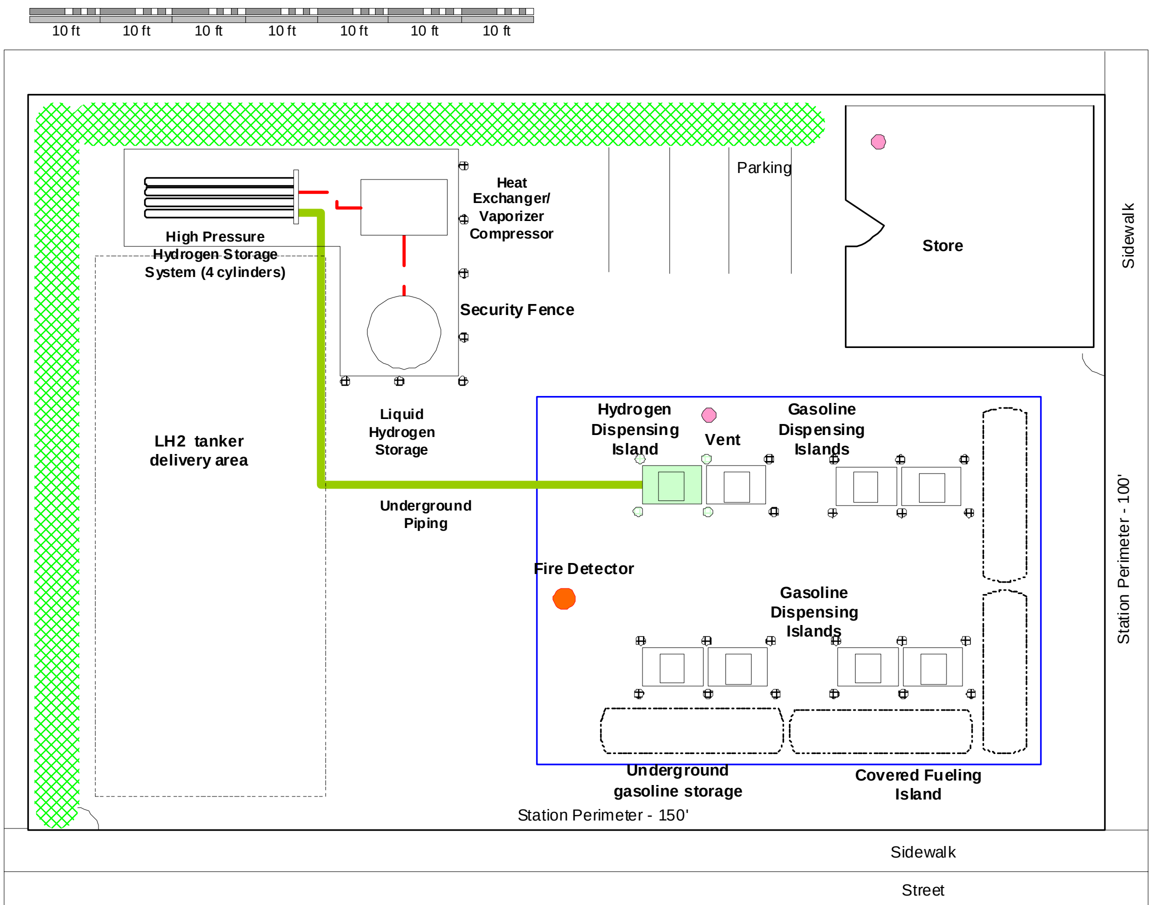


Property of: TIAX LLC 1061 De Anza Blvd. Cupertino, CA 95014	Site Plan - Fueling Station **Combined SMR Hydrogen and Gasoline High Volume Station**			
	SIZE A	DWG BY Erin Kassoy	DWG NO D0228 - S0025	REV 2
10 ft		Mar. 24 2004	SHEET	1 OF 1



Property of: TIAX LLC 1061 De Anza Blvd. Cupertino, CA 95014	Site Plan - Fueling Station			
	Combined Small Volume Liquid Hydrogen and Gasoline Station			
	SIZE A	DWG BY Erin Kassoy	DWG NO D0228 - S0027	REV 3
10 ft		Mar. 24 2004	SHEET 1 OF 1	

Figure 2: Service Station Load Profile